Running head: HELMET SELECTION

Evaluation of Fire Helmets for Daytona Beach Fire Department

Kristine M. Gray

Daytona Beach Fire Department, Daytona Beach, Florida

Appendix E through Appendix J Not Included. Please visit the Learning Resource Center on the Web at http://www.lrc.dhs.gov/ to learn how to obtain this report in its entirety through Interlibrary Loan.

CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed_____

ABSTRACT

One problem discovered by Daytona Beach Fire Department (DBFD) was that firefighters currently use fire helmets that cannot adjust to every head shape creating discomfort, fatigue, and physical interference with work. The purpose of this research project was to determine what fire helmets will aid DBFD firefighters with their work. Historical and descriptive research was used to find out what helmet standards exist and what helmet options were available to DBFD. Evaluative research was conducted to determine what helmets provide the best fit for the majority of firefighters to include hair and head-shape influences. Evaluative and descriptive research was used to find out what helmet had the most safety features. Procedures included: (a) an extensive literature review, (b) firefighter participation in trials for range of motion and visual obstruction using 5 helmets, (c) statistical analysis using SPSS version 17.0 and frequency counts in Excel, and (d) interpretation of the data. It was discovered that firefighters prefer a traditional style helmet and that some helmets were significantly less obstructive to the vision while working than others. The recommendations were that Daytona Beach Fire Department would begin to phase the Cairns 1044 helmet into its inventory and encourage more studies and improvements in the fire helmet arena.

TABLE OF CONTENTS

EVALUATION OF FIRE HELMETS FOR DAYTONA BEACH FIRE DEPARTMENT

The City of Daytona Beach is touted as the World's Most Famous Beach and is located on the east coast of central Florida. The city is surrounded by the Atlantic Ocean on the east and small communities to the north and south. To the west is wild land interface that borders towns which are considered suburbs of Orlando. Two major highways run through Daytona Beach, Interstate 4 heading east and west and Interstate 95 which travels north and south.

The population of Daytona Beach is 66,941 (United States Census, 2000). However, according to Halifax Area Chamber of Commerce (2008) during the work week, the population doubles to approximately 130,000. During special events, such as the Daytona 500 NASCAR race and college spring break that draw national attention, our population explodes to over 300,000 people.

DBFD celebrated its one hundredth year as a fire department in 2009. Tradition was celebrated all year with a centennial badge worn on firefighter uniforms. Calendars were printed exposing family traditions of becoming DBFD firefighters. The pictures included dive gear, motorcycle gear, and firefighting bunker gear and helmets. The fire helmet is a traditional symbol of the firefighter and an important part of the firefighting gear.

Daytona Beach Fire Department (DBFD) responded to 17,613 calls for service in 2009 (DBFD,2009). Of those calls, 10,237 were of non-hazard nature and 7,376 required protective gear of some sort other than for medical protection. Donning, performing in, and doffing gear occurs daily at DBFD. On average, there are 20 calls per day that might require a firefighter to wear a helmet (Daytona Beach Fire Department, 2009).

The problem is DBFD firefighters wear fire helmets that cannot adjust to every head shape creating discomfort, fatigue, and physical interference with work. The purpose of this

research project is to determine what fire helmets will aid DBFD firefighters with their work. This research will utilize historical, descriptive, and evaluative methods to answer the following questions: (a) What helmet standards and ratings exist? (b) What helmet options are available to Daytona Beach Firefighters? (c) What helmets provide the best fit for the majority to include hair and head-shape influences? (d) What helmets provide the most safety features? The hypothesis is that the current fire helmet, Paul Conway American Classic, used by DBFD is less effective than current alternatives.

BACKGROUND AND SIGNIFICANCE

The Daytona Beach Fire Department (DBFD) has 124 employees distributed over five divisions; Operations, Training, Emergency Management, Fire Safety, and Administration. Of those employees, 112 of those are firefighters. There are seven fire stations that house seven advanced life support (ALS) engine companies, three ALS transport capable rescue trucks, one basic life support (BLS) tower truck, and one battalion command vehicle. The department has many special teams that require specialty training and equipment.

Firefighters have wildfire helmets, high angle rescue helmets, motorcycle helmets, and structure fire helmets for use at the department. Fire Chiefs of the DBFD have shown preference in helmet styles over the years. Currently, the structure helmets are of the traditional style with the metal eagle on top and large scooping back. The Paul Conway American Classic traditional style helmet has been the standard issue helmet for DBFD firefighters for many years.

During training exercises and at incidents, personal observation and photos show DBFD firefighters with fire helmets falling off, crooked, and constantly needing readjustment. Often, helmets are removed in order to fit in a vehicle during vehicle extrication, thus leaving the

firefighter unprotected. Firefighters have been known to complain of neck or back pain after extended use of the helmet.

The safety of the firefighters is in jeopardy if the helmet that is supposed to protect them is not worn or is interfering with their ability to do work. Several probationary firefighters have had difficulty completing their probationary testing due to equipment, such as the helmet, obstructing their progress. Knowing these challenges, the DBFD interim Fire Chief, James Bland, wanted to explore other fire helmet options. When this applied research topic was mentioned to him, he was ready to participate in the study himself.

After all, the Fire Chief is in charge of the overall safety of the department. He is the incident commander of everyday operations. In this sense, he performs capability assessments. In the Executive Analysis of Fire Service Operations in Emergency Management (EAFSOEM) class manual (National Fire Academy, 2010), "capability assessment is key to preparedness." The Fire Chief sees that poor fitting helmets decrease capabilities. So, improving helmet fit, will improve firefighter capability.

In that same EAFSOEM chapter, there is a discussion of the historical role of the fire service (National Fire Academy, 2010). High dollar loss to insurance companies created a desire to prevent fires or utilize protection engineering to decrease losses. This, in turn, increases life safety. The fire department began focusing more on life safety over property protection. Codes were created based on life safety. This type of change in the fire service happens when there is a demand. Technology is evolving and improvements to fire helmets are occurring constantly. Some of the reasons for these changes are based on National Fire Protection Association (NFPA) standards.

The NFPA standards are in place to assist the United States Fire Administration (USFA) in obtaining their operational objectives. Improving firefighter safety through better helmets will reduce risk at the local level through prevention and mitigation and it will improve capabilities. Our image as professionals will be improved when firefighters work harder, look more in control of helmets, and finish jobs with less fatigue.

LITERATURE REVIEW

The literature review was conducted to gather historical and descriptive information about helmets in order to assist in answering some of the research questions. Manufacture pamphlets and sales information, manuals and books, and the internet provided information on this topic.

Helmet Standards

Helmets are made to protect heads. Helmets are worn to play sports and ride bicycles and motorcycles. They are worn for many jobs to include military, construction, and the fire service. Some Industries have helmet standards. NFPA 1971 contains the current standards for helmets in the fire service (National Fire Protection Association, 2007).

Some standards have evolved through tradition and history (FOOLS International, 2008). The Fraternal Order of Leatherheads Society (FOOLS) is a group that started in Central Florida in 1995. The website lists over seven thousand members. A firefighter who wears a leather helmet is considered a leatherhead. According to the site, “The Leather Helmet, is an international sign of a Firefighter, a symbol that is significant in not only tradition from the early years of firefighting, but one of bravery, integrity, honor, and pride. The helmet is a sign of who we are, not what we are (FOOLS International, 2008).”

Another influential group of fire service individuals is the International Association of Women in Fire and Emergency Services (IAWFES). This organization conducts a survey every 5 years. In a recent survey, Hulett, Bendick, Thomas, and Moccio (2008) reported that at least 28.4 percent of women in the fire service reported fit problems with the fire helmet assigned to them. This group has spent many hours over the years working on various fit issues for firefighters.

The safety standard for bicycle helmets is written in a federal register by the consumer product safety commission (Federal Register, 1998). After meeting several manufacturing material guidelines, each bicycle helmet must pass 18 detailed tests conducted to specific criteria. Factors tested include peripheral field of vision, positional stability, retention system strength, and impact under several different conditions (Federal Register, 1998).

Motorcycle helmets sold in the United States must meet United States Department of Transportation (DOT) standards (Federal Register, 2001). The helmets may have labels that list other standards of certification to include a Britain standard, European standard, and the Snell standard. According to an article in Motorcyclist magazine, standards are not standardized. So, it makes deciphering what you are buying very difficult (Motorcyclist, 2009). Motorcyclist magazine contends that there are so many factors involved in determining which helmet would be safest and that the certification does not always mean one helmet will perform better than another. The magazine states that price had no relation to safety. Cheaper plastic outer shell helmets performed better than more expensive fiberglass outer shells in their trials. Another concern raised was why certain tests conducted were repeated on the helmet in the same location. The magazine states it would be rare for the head to hit on the exact same spot a second time. Motorcyclist magazine continues to discuss the debate about helmet performance and “searching

for the truth behind motorcycle helmet design, helmet standards, and actual head protection (Motorcyclist, 2009)."

Military fighter pilot helmets have standards that surpass land based helmets. The needs for these types of helmets are different. The purpose is more for communication, oxygen provision, vision, or other advanced technology versus impact protection like the new Terminator-style helmets described by Matthew Hickley (2007). Aside from the above mentioned functions of this type of helmet, there are twin projectors that beam images on to the inside of the tinted visor. The images are gathered from cameras outside the plane. Therefore, the wearer can literally see through the plane.

In an article by Anacan, "current fighter pilot helmets do more than provide protection; they actually help a pilot become a better pilot. Rather than simply helping the pilot avoid injury or death in the event of an ejection or crash, modern helmets can help the pilot avoid situations that would result in possible injury or death (Anacan, 2010)." Helmet technology has been taken to a new level.

Helmet Manufacture Options

Manufacturing companies offer a wide array of helmets. Different companies emphasize different characteristics in their helmets as seen by the information offered. For example, some companies offer research information to potential buyers of their fire helmets. Bullard (Bullard, 2009) published an article that assists a firefighter in choosing a fire helmet. Phenix Technology offers a list of affidavits from happy customers to market their helmets while Lion Apparel and Paul Conway provide science of comfort facts and helmet wear test protocols.

Bullard (Bullard, 2009) classifies the key elements in choosing a helmet as weight, composition, style, and balance. They admit that their helmets do not have much of a difference

in weight as compared to other helmets. Their statement is that the design and engineering make their helmet more comfortable and therefore, it feels lighter. Bullard only mentions fiberglass, or composite, and thermoplastic shells for their helmets but they do not mention leather. They also only mention traditional style and contemporary style with no mention of European style. Traditional style has the brass eagle while the contemporary style is sleeker. Photos can be seen in appendix A. Under the balance category Bullard states, "Did you know that you can make your helmet feel lighter…without actually removing any weight? It's all about balance (Bullard, 2009)."

Phenix Technology (Phenix Technology, 2010) is marketing their fire helmets by showing the comments made by many firefighters. Many of the leather helmet owners claim that the helmet is very comfortable and lightweight. One customer mentions that the balance and comfort are better than the Cairns brand. Instead of showing facts to firefighters, this company chooses to quote satisfied customers.

Lion Apparel published several article containing scientific facts about fire helmets. In the first article (Lion Apparel, March 2003), comfort of the helmet is dissected. The company clearly states that every person's head is unique. Adjustment to fit different heads is key to having a comfortable helmet. "It directly corresponds to how closely the fit of your helmet matches the dimensions of your head (Lion Apparel, March 2003)."

Safety factors are tied into the comfort and weight issues. First the article states, "It's well established that a comfortable helmet will be worn longer with less fatigue (Lion Apparel, March 2003)." Advances in technology have shown that a heavier helmet is not always more protective. So, Lion continues to state, "Unnecessary weight is seldom a good thing for fire fighters. It can increase your metabolic stress and reduce your stamina in high-exertion situations

(Lion Apparel, March 2003).” The center of gravity, headband height, and cushioning are all explained to the reader in order to provide an educated future helmet wearer. Knowing how to properly fit a Lion Apparel helmet should make them more comfortable.

In another article (Lion Apparel, November 2004), the science is all about the reasons for wearing helmets, ideas about why head injuries to fire fighters are infrequent, and the three components of the helmet. It is believed that since fire fighters wear their helmets but may not wear hoods or breathing apparatus, other types of injuries are more common. This leads Lion Apparel to believe that the helmet is working as a head protector. NFPA testing and strict requirements are mentioned. The hard outer shell, the energy absorption system, and the suspension system are the three components that have to work together to make the helmet the best in its class. An example of how each component plays its role in the unit is given.

A *Helmet wear test protocol* (2010) from Paul Conway lists 8 categories that this helmet manufacturer believes should be utilized to find a proper fitting helmet. The company lists several other brand helmets that can be compared to find out what helmets fire departments are considering. The company has an evaluation form that the company can review for the helmet wear test protocol.

Evaluations

Training and assistance was provided during this study by Florida Safety Program Manager Charles Brush of the Bureau of Fire Standards and Training, Doctor Cathy Moutsopoulos of Beachside Chiropractic, and Dr. Shawn Doherty of Embry Riddle Aeronautical University. Several interviews were conducted to gather expert information and tools related to this project.

Charles Brush talks to students in classes at the state fire college about helmet safety. A DBFD fire fighter, who was in one of the classes, suggested that he be contacted in reference to this project. Through various emails, Charles Brush provided his thoughts about helmet safety and some of the helmets for use in the trials. In his expert opinion, as the state safety professional, he wrote his top five concerns that should be considered in conducting helmet trials or helmet research (Brush, personal communication, May 15, 2010). He first mentioned testing the fire fighter in crawling mode to see if the helmet falls off the head or stays on. Range of motion for the head with the helmet on was another issue. He thought that the helmet weight itself should be known. He wanted to know whether the balance of the helmet was consistent with the balance of the head. Then, he wanted to test the survivability or injury potential of each helmet when hit by front, back, and side blows. During some telephone and email conversations, Charles Brush divulged a wealth of knowledge related to helmets, including history, NFPA standards and industry politics, and places to look for more information. He stated that the brass eagle served a purpose years ago. The fire fighters would hold the helmet in their hand, swing it into a window so the eagle would break the glass. Then, the fire fighter would put the helmet on and go inside (Brush, personal communication, June 25, 2010).

Doctor Cathy Moutsopoulos was contacted based on advice from Charles Brush. She provided the goniometer to test range of motion in the study. In her expert opinion, she thought that the weight of the helmets will definitely affect the work output of a fire fighter. She did not know if there were many articles about axial pressure on the cervical spine but she thought that was just common knowledge among chiropractors. Weight on the spine creates extra work on the whole body (Moutsopoulos, personal communication, June 18 and 21, 2010).

Work and the human body is a specific subject area called human factors engineering. Embry Riddle Aeronautical University in Daytona Beach Florida has a program of study for this discipline. Professor Shawn Doherty is the expert instructor in applied statistics and research for human factors engineering. During phone conversations and emails, Dr. Doherty provided guidance so that the research in this study would be valuable. He also provided the computer programming used to analyze the results. During one training session, he had many questions for how the data would be collected. How the data is collected impacts the analysis. For his example, he stated that if the same firefighter was exposed to all conditions instead of a different firefighter for each condition, then overall less firefighters would be needed (Doherty, personal communication, April 29, 2010).

In summary, there is a lot of information about helmets. All of the literature and interviews impact this study and helped form the basis for this project. The standards for helmets have a long history that is evolving and controversial. The helmet options provided a review of the emphasis that manufacturers place on helmet characteristics as well as the scientific methods used by manufacturers. The helmet evaluation was developed based on the literature review. So, the reading and delving into research formed the foundation for the rest of this project.

PROCEDURES

Descriptive, historical, and evaluative research was used in this study. The first step was to conduct some research about helmets through electronic media, sales representatives, safety experts, and other media. Helmet usage data was limited to how many incidents were listed in the Firehouse software program. Otherwise, knowledge of helmet styles worn by DBFD is limited to photographs and memory of firefighters. Record keeping for purchases of helmets

dates back to only the last ten years. Reading new research and reviewing historical data of the DBFD lead to the development of the evaluation portion of this project. The first and second research questions related to helmet standards and helmet options were able to be answered mostly with the literature review. The third question related to best helmet fit involved a helmet trial using firefighters from DBFD. The fourth research question related to helmet safety entailed a combination of literature review and the results of the helmet trial.

As a starting point, research had to be conducted to refine the problem statement regarding helmet fit for DBFD. Personal stories from several firefighters and emails from the fire chief triggered the thought process that there is a concern about this issue at the Daytona Beach Fire Department. Then, a public records search of available information was done. The library and the internet provided valuable information that was narrowed down to the key facts needed for this research.

Emails were sent and phone calls were made to local sales representatives and manufacturers to acquire helmets for use in the study. After weeks without luck, Charles Brush donated two helmets. A volunteer firefighter of the county fire department loaned a helmet for use in the trial. One helmet is the DBFD current helmet. The final helmet was purchased for use in this study based on prompting of a sales representative.

The helmets were weighed on a produce scale at the grocery store in the checkout line. This scale is assumed to be accurate according the standards and legal requirements for scales that determine price for a product. The helmets were placed completely on the scale while in stable balance.

Prices for helmets were estimated by the sales representative for MSA products, Monte Sims. He sells each of the helmets or their equivalent that are in the trial. He mentioned that the

traditional style helmets require an extra purchase of a leather front. Shield options can change the price of the helmet, as well.

Recruitment for the helmet trials began simultaneously to the development of the trials. See appendix B for a copy of the email flyer that went to all DBFD employees. No firefighters were excluded from the trial. The request for participants in the trial was created to gather interested participants for the study. Forty participants completed the study. Since the training division of the department only allowed three consecutive days for the trials and did not mandate attendance at this training, creative rewards were needed to entice volunteers to participate. Donations from Hawaiian Tropic, Dr. Moutsopoulos, and this author filled two reward bags for each participant.

A training outline was created to allow this project to teach each participant a bit about helmet safety. Others asked many questions to become more familiar with the different options. The training outline can be found in appendix C. The training outline includes every aspect of conducting the trial. The training was repeated on 3 different days to allow participation of firefighters from each shift while on duty. The training division provided a signature sheet for each shift to create a record of who participated. The list of participants is in appendix D. Coincidentally, the helmet safety study was done during National Safety Week and all involved received a certificate of appreciation and participation to be placed in their employment file.

Obtaining volunteers to be assistants was through delegation of crew and family members. The first day of the trial was the duty day of the trial organizer and the day off for Michael Gray, her husband. Therefore, he was recruited to obtain all range of motion data for the first trial day. An engine crew member was assigned to be the observer for the obstruction

count through the crawling obstacle. On the second and third day of the trials, the organizer was off duty. Therefore, teenage daughters, Josie Gray and Lea Gray, were recruited to fulfill the assistant duties. Lea was the range of motion measurer while Josie was the crawling observer. Consistency in observation was stressed to all assistants throughout the trials. This was enhanced through a standardized data collection sheet as shown in appendix E and F.

When the firefighters arrived as designated by their supervisor for scheduling purposes, they were given a brief explanation of the reason for this helmet safety study and their role in it. They were instructed to wear the training air pack presented to them after they signed the roster. The range of motion assistant handed them one of the five helmets that were labeled with bold yellow sticky sheets and bold black ink as a number designation. See Appendix A for photos of each of the five helmets and Table 1 for helmet attributes.

Table 1.

Helmet attributes

Helmet #	Name	Cost	Weight
1	Paul Conway American Classic	$212.00 + $38.00 front	4.09 lb
2	Morning Pride Modern 1996	$135.00	3.45 lb
3	Cairns 1044	$172.00 +$38.00 front	3.67 lb
4	Cairns Philadelphia 1984	$135.00	2.37 lb
5	Gallet Fire Knight	$290.00	3.02 lb

The assistant then obtained the range of motion with a goniometer provided by Dr. Moutsopoulos for that helmet with the breathing apparatus. Then, the other assistant lead the participant to the crawling exercise. The exercise evolution was approximately 20 linear feet

with a corner, an obstacle on each side, a weight rack to crawl under, 180 degree turn around, and the weight rack to step over. As the firefighter crawled, each was told to work as if in a fire, by feeling the surroundings and maneuvering under, over, or around obstacles (see figure 1).

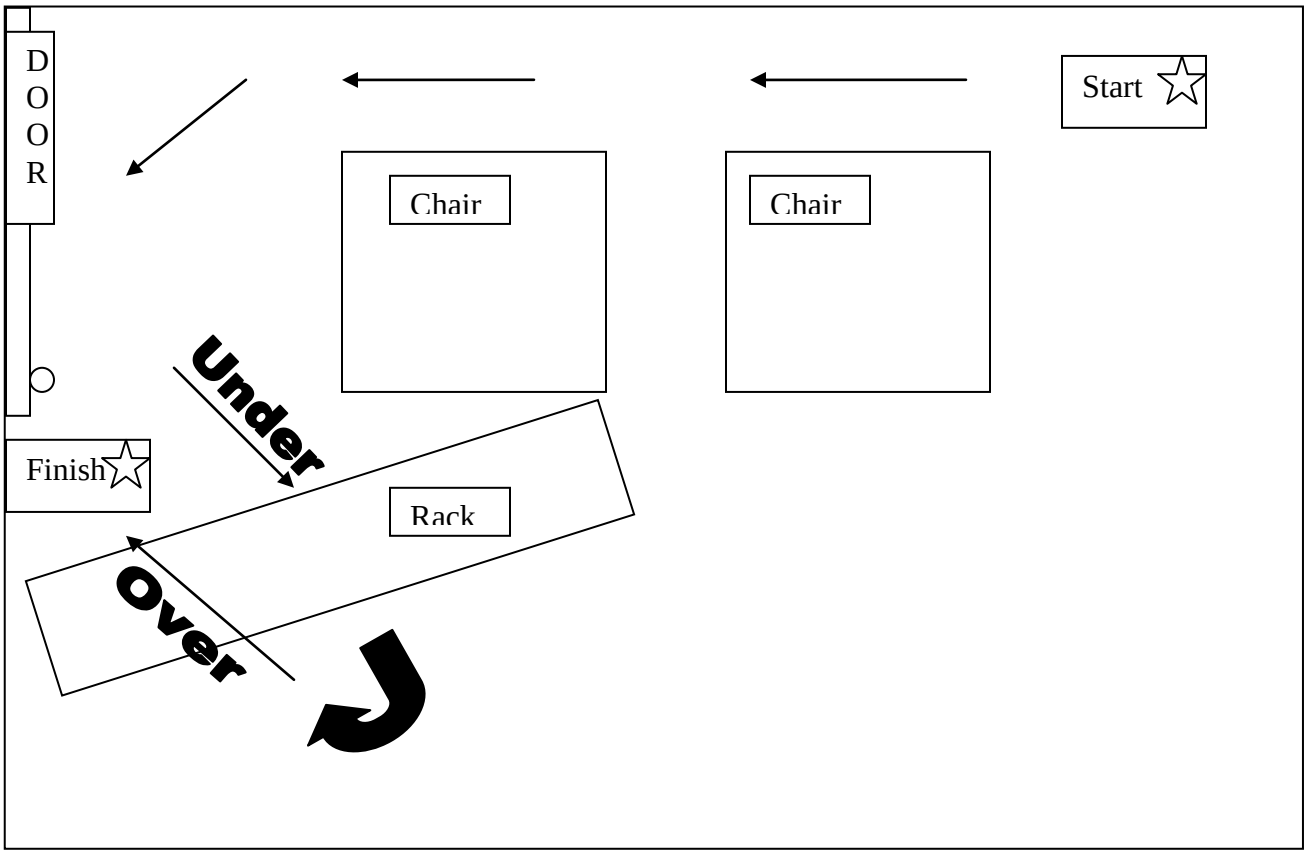

Figure 1: A schematic of crawling exercise.

In addition, the participant was to count each time that he felt or thought the helmet needed to be adjusted or if it got into the line of sight. The assistant was to observe when she felt the firefighter had an obstruction or had to readjust the helmet. The reason for this was to ensure that obvious readjustments were not overlooked by firefighters who were used to readjusting or adapting without awareness and to determine if some obstructions were less obvious to the viewer than the wearer. It was meant to be a check and balance against the firefighters to keep the results as true and honest as possible. The firefighter then returned to the beginning to

repeat this process for the next helmet until all five helmets were worn. Participants viewed the helmets in a random order to reduce experience effects. Then, firefighters completed a survey ranking the helmets on four different characteristics. Once complete, the firefighter was given reward bags and released from training.

When the training outline and roster were turned in to administration, awards were printed and signed by the organizer and the fire chief. Administration placed a copy in each firefighters file. The original was distributed to the participants. A copy can be viewed in appendix G.

All of these procedures were an effort to test the hypothesis that the Paul Conway helmet used by DBFD is less effective than current alternatives. In order to test the hypothesis, one variable of helmet type with five levels of that independent variable with dependant variables of range of motion, participant count of obstruction, and observer count of obstruction, and participant ratings on four dimensions were part of the project. All analyses were done at alpha equals .05 to determine significance.

Once the data collection was complete, it was entered into an Excel spreadsheet in the form of raw data and can be found in appendix H. Then, the SPSS version 17.0 statistical analysis program was used to analyze the data. A repeated measures Analysis of Variance (ANOVA) was used as the appropriate statistical test for determining if there was a difference in the helmets. Appendix I has the results of the analysis. The Bonferonni post-hoc comparison was used to show the relationship of the differences between the helmets.

The survey data was tallied on an excel spreadsheet. A frequency count was conducted. Each characteristic was given a count for how many times each helmet was chosen at each ranking with one being the best ranking and five being the worst ranking. For example, a

firefighter may rank helmet 1 as best in appearance and might rank helmet 1 third best in fit. The total count for each characteristic in each category would be a maximum of forty. This opinion section is used to show how the subject felt about each helmet despite the results of the other tests. The results can be reviewed in appendix J.

The research was conducted under the assumption that the data was obtained from a large enough sample of DBFD firefighters. There are 112 uniformed positions with 103 dedicated to line operations. At the time of this study, there were at least three positions unfilled. So, 40 people out of 100 are 40 percent. It is assumed that the sample contained a variety of people that would match the demographics of the entire DBFD population based on fundamental statistical principles.

The limitations were participation was voluntary, helmet selection was small, and the time frame was short. The helmets were bought or borrowed. So, two of the helmets were over 10 years old. This means they were not necessarily current with technology or to NFPA standard to date. Manufacturers and sales representatives, names withheld per request, were not willing to provide any helmets for this trial unless the helmet was purchased. Developing the helmet trials was somewhat restricted by the project timeline. In order to test a large sample from the DBFD, the test had to be limited to 15 minutes per individual. So, the area of study had to be narrowed to range of motion of each helmet and how many times the helmet obstructed firefighter vision in a simple crawling exercise.

Finally, all of the information was combined to produce these results and recommendations that follow. Throughout the entire process, participants were given credit but the individual results remain confidential.

RESULTS

The data was investigated for outlying performance and none was found. The survey ranking data was reviewed for frequency counts while the other dependant variables: (a) range of motion, (b) firefighter obstruction tally, (c) observer obstruction tally were investigated through a repeated measures ANOVA with Bonferonni post-hoc tests, all at an alpha level of .05.

The results for the first research question to determine the national standards and ratings for helmets are vast and detailed. Some are culture standards. The standards for motorcycles and bicycles require testing with very detailed specifications, however there is other certification available that is not required. Fire helmets have only one written document to follow, NFPA 1971. Under NFPA 1971, fire helmets have to undergo testing similar to other industry helmets. In addition, fire helmets undergo flame resistant tests. The unwritten standard for fire helmets is the traditional culture. In the bicycle helmet tests, the head-form varies in size for infants, children, young adults, and adults. Fire helmets are tested on a male headform of the 50^{th} percentile. Fire helmets undergo many strength test and force tests. They do not undergo individual wear tests to show if it actually stays on a human head during use.

The second research question sought to find out what options were available. The options were limited to helmets under $300.00. The fire chief did not declare any constraints but did advise that the budget is tight and all efforts should be made to reduce spending. All of the helmets tested, or the current equivalents, were within that limit as stated in Table 1. The cost, weight, and name of the 5 helmets are listed in Table 1.

When the subjective survey data frequency counts (shown in appendix J) were examined for helmet rankings along the four dimensions of fit, adjustability, safety, and appearance, the

Fire Knight helmet was ranked as most liked for fit, adjustability and safest per the frequency chart but was the least desired in appearance. The Morning Pride helmet was also ranked as the most liked for fit and adjustability. It was solid in the middle for appearance and safety rank. The Cairns Philadelphia helmet was liked the least in appearance, adjustability, and safety. The Paul Conway helmet was ranked most liked for appearance and was in the middle for safety but was all over the board with mixed reviews on fit and adjustability. The Cairns 1044 helmet ranked high for appearance, adjustability, safety, and fit. Based on survey frequency count data, the Cairns 1044 helmet was the highest rated in all four categories when compared to the other helmets under the subjective ratings.

The third research question sought to examine what helmet provides the best fit for the majority to include hair and head shape influences. According to the SPSS analysis of the repeated measures ANOVA (see appendix I) on the range of motion data, there was a difference in the range of motion between the five helmets, $|F|\ (4,156)=2.546,\ p=.042.$. However, using a Bonferroni post-hoc comparison to examine where the overall difference in range of motion occurs between the helmets, the only helmets that show a significant difference in comparison to each other are helmet 4 and 5, $p=.046$. All other comparisons were non-significant for the range of motion variable. Helmet 5, the Fire Knight, had more range of motion than helmet 4, the Cairns Philedelphia. The average differences are plotted in appendix I. The lower range is just about 41 degrees on average, while the upper range is just about 43 degrees on average. The difference that occurred was noticeable and mentioned by the participants when conducting the second portion of the trial in the crawling experience.

Through SPSS, the firefighter obstruction frequency (see appendix I) showed overall that there was a difference in the frequency of obstruction as recorded by the firefighter,

$|F|(4,156\_=15.878, p=.000.$ When comparing the firefighter obstruction frequency in a pairwise comparison, the Bonferroni post-hoc, helmets 1 and 5 had the most significant difference, *p=.000*. The Fire Knight, helmet 5, had much less obstruction than the Paul Conway, helmet 1, in the firefighters frequency count. (see firefighter obstruction frequency graph in appendix I) The Paul Conway was also considered different from helmet 2, *p=.000,* and helmet 3, *p=.002,* but not significantly different from helmet 4, *p=1.000*. Helmet 2, the Morning Pride, was considered similar to helmets 3, *p=1.000,* and 4, *p=.693,* but different from helmet 1, *p=.000,* and 5, *p=.009*. Helmet 3, the Cairns 1044, is similar to helmet 2, *p=1.000,* and helmet 4, *p=1.000,* but significantly different from helmets 1, *p=.002,* and 5, *p=.000*. Helmet 4, the Cairns Philadelphia was only considered significantly different from helmet 5, *p=.000*. Helmet 5, the Fire Knight, was considered significantly different from all of the other helmets, *p=.000, .009, .000, .000*.

When the observer tallied the frequency of obstruction, the differences were similar to the firefighter tally of obstruction with a slightly greater difference in helmet 1 as can be seen in the rater obstruction frequency graph in appendix I. Through the SPSS repeated measures ANOVA for the rater obstruction frequency a difference is shown, $|F|\ (4,156) =25.572, p=.000.$ The Bonferroni post-hoc comparison shows where this difference occurs. Helmet 1, the Paul Conway helmet, was not similar to any of the other helmets, *p=.000, .000, .002, .000*. Helmets 2, 3, and 4 were considered similar, *p=1.000*. Helmet 5, the Gallet Fire Knight helmet, was again significantly different from the others, *p=.000*.

The results for the fourth research question about what helmet provides the most safety features returned to subjective information. Since there was no study found on safety features beyond the NFPA required safety, all literature and test results gathered were opinions of trial

participants and opinions of manufacturers trying to sell their product. The frequency test showed that helmet 2, 3, and 5 ranked best in the safety category.

DISCUSSION

At the beginning of this research, the problem was clear that the current DBFD helmets did not provide the best fit for all firefighters. The results of this study clearly showed that to be true. Strangely, the firefighters still had strong feelings for the appearance of the current fire helmet as shown by the preference survey data. Current mindset links traditional style fire helmets as the favored look despite their fit and obstruction of vision. Since the preference data was gathered after the crawling experience and many of the participants still ranked the traditional helmets higher than the European helmet that interfered less with their vision, there must be a bias attitude in what a safe fire helmet should look like. This apparent resistance to change is fed by Fools International (2008) and fire chiefs who identify that look with a real firefighter. The image is of a helmet with the ornate style, large scoop back, and brass eagle or bigger is better.

Leather helmets were out of the expense range for this study. Therefore, no information is known how a leather helmet compares to any other helmet. For example, the cushion provided by a leather helmet may be better as mentioned in the article in Motorcyclist (2009) when they discuss that the different shells of helmets make a big difference in the helmet effectiveness. What is understood is the appearance of plastic or fiberglass helmets are replicated after the traditional leather helmet. Therefore, firefighters want to pick this helmet as a favorite but it may not have the same qualities as the leather helmet. It only looks like the original. So, when technology brings forth new safety innovations, it is difficult to incorporate the technology into the old look. As the Fools International (2008) state on the website, “We believe that it is our

duty to be as well trained as we possibly can. This can only keep us, and our brothers and sisters safe on the fire ground" (p.1).

Safety is a big part of the FOOLS. They honor the symbolism and history that firefighters should uphold. The core values are listed in the training portion of the website. The story behind the Maltese cross, another legendary firefighter symbol, is also available on their website. Prudence, temperance, justice, and fortitude are the values embedded in the Maltese cross symbol. FOOLS makes it clear that they are all about the values behind the symbol; they are not the symbol itself (Fools International, 2008). So, eventually, the traditional fire helmet may evolve into an advanced technological wonder like the fighter pilot helmets, much like the Maltese cross has evolved over the years.

According to Hulett et al. (2008) the fire service continues to have fire helmet fit issues for women. "…the average woman has a body size 93% of the average man's, and a 50^{th} percentile woman corresponds to a 5^{th} percentile man" (p. 7). Therefore, the 50^{th} percentile male headform that is used in standardized testing is not even close for the 50^{th} percentile woman. This stands to reason that helmet standards need to be reevaluated to account for more head sizes. Hulett et al. states that there were also many issues with the interaction of the breathing apparatus hitting the helmet and pushing them forward to obstruct vision. This study showed that with the current DBFD breathing apparatus, the helmets had different ranges of motion. It is possible that with a different style of breathing apparatus that the ranges of motion might increase or decrease. This study shows that there is interaction that affects the range of motion. The size and gender of the participants were not included in this study. However, it is assumed that this sample included all different size participants. This study indicated that there are issues with helmet fit.

Since there are so many factors involved in properly fitting helmets, the Paul Conway *Helmet wear test protocol* (2008) was used to narrow the factors. The list contains protection, weight, durability, comfort, fit/function, appearance, balance and stability, and head/neck fatigue. These items appear to be what firefighters value in a proper fitting helmet. Although not every factor could be studied in this project, each has merit in choosing the right helmet for purchase.

The logic for which the procedures of this project were created is based on conducting valid research within the effective deadline. While the weight is important, it is more about the distribution of the weight. Objectively testing this without expensive lab equipment would be out of the scope of this project. Protection is covered by the NFPA standards but could probably be studied at greater length with a research team with a lot of money. Durability study would take too long. Comfort, fit/function, balance and stability, and head/neck fatigue were grouped together in this study under the fit category. They were also tested in the range of motion and crawling exercise. The fatigue rating actually requires a greater length of time on the head than was available. However, if a helmet is uncomfortable after only a short time, it is not going to get any more comfortable. Therefore, it was more important to decide which helmet was more tolerable in the neck comfort arena based on the 5 available helmets. The appearance of the helmet was included based on a hunch, a hint from Charles Brush, and the literature reviewed that it played a role in what firefighters wanted to wear. The safety portion was added to this study to enhance the experience of the firefighters in the trial. By requiring them to consider all factors of each helmet in the study in respect to safety, they learned more about what makes a safer helmet. In testing the different helmets, some of the firefighters were teaching themselves

about what was safe in a helmet. Many of them even mentioned studying more about the different helmets and safety features.

Several comments were noted during the helmet trials. Some were heard to say that they did not want to look like Marvin the Martian of cartoons, referring to the Fire Knight helmet. They were immediately turned off by the look. However, after trying the helmet on, they could see that there was a difference in how they could maneuver. There was much less interference with work and greater vision overall. As stated in the results, the Fire Knight helmet was significantly better in the firefighter obstruction tally from the other 4 helmets. As well as in the observer obstruction tally, the Fire Knight was significantly better than all of the other helmets. Our current helmet, the Paul Conway was shown as significantly worse than all of the other 4 helmets in the firefighter obstruction frequency and rater obstruction frequency. The other 3 helmets were in the middle of the road with little significant difference from each other in the firefighter obstruction frequency and rater obstruction frequency.

If a firefighter felt uncomfortable or unsafe in a particular helmet, it was more than likely not as safe as the other options. This line of thinking is pointed out in articles by Bullard (2009) and Lion Apparel (2003) about comfort. Many firefighters were uncomfortable in our current helmets as heard when they completed the crawling obstacle. This implies that changing to a different helmet is a wise decision for DBFD.

The simple fact that Phenix (2010) lists multiple quotes from helmet owners that reference their satisfaction in the comfort of their helmet shows that even the marketers feel the firefighters will choose a helmet based on its comfort level. On that same idea, Lion Apparel (2004, science of comfort section) creates the articles that depict the scientific equation for how they make a great fitting helmet. “Since no two heads are alike, this requires certain components

of the helmet be adjustable so each can properly fit your head's unique size and shape" Ironically, the Lion Apparel helmet, Paul Conway, was the least liked in fit and not well ranked in adjustability.

Both the Federal Registers for bicycle (1998) and motorcycle (2001) helmets include critical testing certification similar to fire helmets. When the helmets pass these standards, they are meant to be the safest protection designed for that particular use. However, just like fire helmets, if it doesn't fit correctly, all of those certification tests don't mean much. Also, if someone wears a helmet that is too hard, it can cause as much damage as if the person was not wearing it. Or as Motorcyclist (2009, p. 3) puts it, "If they'd had a softer helmet they'd have been better off." Basically, if there isn't enough cushion to diffuse the blow from a wreck, then the brain suffers a diffused injury. That type of injury is not repairable. A softer helmet should also mean it could be lighter or less dense. Thus, some of the desired qualities of lighter weight for the wearer to bear and more shock absorbing could improve the helmet by making it safer, more comfortable and more likely to stay in place without obstructing vision.

Motorcyclist (2009, p. 10) points out that size matters. Because a bigger head weighs more than a smaller one, it could handle a blow to the head while wearing a harder helmet. However, the smaller heads would suffer. Likewise, in the fire industry, heads are of varying sizes. There should be more size variance in the purchase options.

Hickley (2007) and Anacan (2010) describe how unique a fighter pilot helmet can be. They both point out that using technology can prevent a collision in the first place. Surely, there is more technology available for fire helmets that can replicate these features. Cost is the biggest barrier that might prevent future improvements to fire helmets. However, sometimes, the new technology is only a simplification of the original. Making a helmet lighter and simpler might be

all that is needed. What if a fire resistant material could be molded to the head like memory foam so changes in hair or shape would not matter? Firefighters are very creative. They often improvise with everyday materials to retrofit any situation. Manufacturers should tap into their ideas by advertising a hotline or website that firefighters could call or enter data at any time with potential benefits to the firefighter who invents a usable solution.

The biggest flaw to be found in this research is that NFPA 1971 (2007) only requires testing on the male headform of the 50th percentile. If the same tests were performed on different size headforms, what would the results be? Many of the helmets may not pass the certification testing. The reason for this is that in the results of this project the each person felt differently about the different helmets. The preference survey showed that not everyone would choose a specific helmet in a specific category as the best in that area. Also, the obstruction frequency data for both the firefighter and the observer illustrated that the helmets are not balance on every head. The helmet may have been balanced on the 50th percentile male headform at the factory. When placed on a head that was not of the 50th percentile, as assumed was the case in some of the participants of this study, the helmet obstructed the firefighter vision or needed readjusting.

RECOMMENDATIONS

A recommendation would be to add more size requirements into the test certification of the NFPA standard. This study shows evidence that different helmets fit differently on the wearer. It also shows that even though each helmet met the NPFA standard, the helmets did not necessarily work well for the firefighter. More testing of some sort should be done with real firefighters actually conducting work similar to real situations. Firefighters can be surveyed to come up with more ideas for helmet improvement options.

This study or another study of this type could prompt fire helmet manufacturers to make a transition helmet that can blend the traditional helmet into the European helmet in a way different from the middle of the road modern style. Maybe a transition helmet could feature the European helmet with a flexible back scoop for those who think the helmet needs more of a water shed option. It could be made of a material like silicone that is heat resistant yet pliable to maintain range of motion and vision. Maybe an eagle could be painted or molded somehow on the front to honor that part of tradition. The fire industry will benefit if more studies of this nature are conducted.

Readers who may wish to replicate this study or continue with further research should decide on a style and then conduct this study with various helmets of that style. Further research should be done on the speed of donning the helmets, the interface with the face piece, and the speed of readjusting if needed for haircut or style that changes the dimensions of the head. More studies should be done on work output comparisons to determine how the weight or balance of the helmet affects the ability to work. The range of motion study could be perfected with more accurate starting and stopping points that include visual benchmarks.

Based on all of the research for this project, recommendations will be made to the Fire Chief of DBFD to purchase the Cairns 1044 helmet because it scored the best in the preference information and scored well in the statistical analysis related to range of motion and obstruction frequency. This is the best solution considering all of the information in the discussion section. Also, the transition would be gradual from the Paul Conway style. Since the look of the Cairns 1044 helmet is very similar to the Paul Conway style, it would not cost as much to buy helmets when possible as needed as the budget allowed. If the budget was better, and the mindset of the department was different, another recommendation would be to further investigate the European

style helmets. During any future research, the trials should be mandatory for the entire department to confirm accuracy in the results.

Gradually changing the helmet to the Cairns 1044 from the Paul Conway will benefit the DBFD. Not only is the Cairns cheaper, but it pleases more firefighters. It is shown to be less obstructive to the firefighters work. A uniform appearance is maintained. The fire chief can show statistically that these helmets create less work for firefighters because the helmet is easier to wear. Therefore, he can be assured his firefighters are wearing gear that will help the firefighters be more productive while wearing the helmet.

REFERENCE LIST

Anacan, R. (2010). *What is a fighter pilot helmet?* Retrieved on April 16, 2010 from http://www.wisegeek.com.

Bullard. (2009). *Choosing a fire helmet*. Retrieved on November 14, 2009 from http://www.bullard.com/V3/products/fire_service/choosing_a_helmet.php.

Daytona Beach Fire Department. (2009). Retrieved from departmental records database. Accessible by public records request, (386) 671-8000.

Federal Register. (March 10, 1998). *Safety standard for bicycle helmets; final rule*. (16 CFR part 1203). Vol.63, no.46: Author.

Federal Register. (October 1, 2001). *Federal motor vehicle safety standards*. (49CFR571.218). vol. 5: Author.

FOOLS International. (2008). Retrieved March 29, 2010 from http://foolsinternational.com.

Halifax Area Chamber of Commerce. (2008). Retrieved October 19, 2008 from http://www.daytonachamber.com.

Helmet wear test protocol. (2010). Retrieved March 26, 2010 from http://www.paulconwayhelmts.bz/weartest.shtml

Hickley, Matthew. (November 9, 2007). MailOnline: The terminator-style helmets that allow fighter pilots to see through their planes. Retrieved June 9, 2010 from http://www.dailymail.co.uk/sciencetech/article-492631.

Hulett, D., Bendick, M., Thomas, S., & Moccio, F. (April 2008). *A National Report Card on Women in Firefighting.* (Available via www.i-women.org)

Lion Apparel. (November 2004). *Helmets: protecting from head injuries*, part1. Vol.MMIV, no. 11.:Author

Lion Apparel. (March 2003). *The science behind a comfortable helmet.* Vol. MMIII, no. 3: Author.

Motorcyclist. (February 2009). *Motorcycle helmet performance: blowing the lid off.* Retrieved April 16, 2010 from http://motorcyclistonline.com/gearbox/motorcycle_helmet_review

National Fire Academy, (2010). *Executive analysis of fire service operations in emergency management.* Emmitsburg, MD: Author.

National Fire Protection Association. (2008). *Standard on helmets for structural fire fighting* (NFPA 1972). Quincy, MA: Author.

National Fire Protection Association. (2008). *Standard on selection, care, and maintenance of protective ensembles for structural fire fighting and proximity fire fighting* (NFPA1851). Quincy, MA: Author.

Phenix Technology. (2010). *Quality helmets & accessories for firefighters*. Retrieved on March 26, 2010 from http://www.phenixfirehelmets.com.

U.S. Census Bureau. (2000). *American factfinder*. Retrieved April 3, 2009, from http://factfinder.census.gov/servlet.

Appendix A

Five Helmet types used in the Study

Paul Conway American Classic Fiberglass

Morning Pride Lite Force Plus

Cairns 1044

Cairns 360

Gallet Fire Knight

Appendix B

Helmet Study Recruitment

From: Gray, Kristine M
Sent: Thursday, June 03, 2010 7:48 PM
To: _All Fire Dept Users
Subject: Free stuff for participation in 15 minute research trial

WHO: All Daytona Beach Firefighters are eligible to participate in this trial.

WHAT: 5 helmets will be tried on with 2 tests conducted for range of motion and stay-ability

WHEN: June 21, 22, 23 (Monday, Tuesday, Wednesday) of 2010 time arranged through Battalion Chief

WHERE: Fire Station # 4

WHY: To be part of a published research project (anonymity can be requested) & to get free stuff

HOW: Send reply email to me, Kris Gray, expressing your ability to participate.

RISKS/SIDE EFFECTS: You might have fun. The free stuff might be cool.

Maximum allowable participants is 112 DBFD firefighters.

Thank you in advance.

Kris Gray

Appendix C

Lesson Plan for Helmet Trials

Instructor: Kristine Gray Dates: June 21-22-23, 2010
Title: Helmet Trials
Specific Topic: Safety study of 5 helmets
Instructional Goal: The students should be able to demonstrate that there are differences in helmets that create concerns in firefighter safety.
Performance Objectives: 1)The participants will have a rating, at the end of the trial, of each helmet in 4 different categories: fit, adjustability, appearance, and safety with each helmet ranked 1 to 5 and 1 being the best helmet in that category. 2) The participants will have two tallies of obstruction for each helmet during crawling evolution and a range of motion for each helmet.
Rationale: Safety is the main reason for this helmet trial. Each participant will notice the different options and feel how some helmets are safer than others. The results will be used in a National Fire Academy Applied Research Project that focuses on helmet safety.
Lesson content: The participants will try on 5 different helmets of various styles. After each helmet, the range of motion in the upward movement of the neck is measured and then the participant crawls a short obstacle course to determine how stable the helmet is while in action. Movement of the helmet is tallied by the participant and an observer to determine how often the helmet interferes with vision or ability to move.
Instructional Procedures: A) An announcement was sent out requesting participation in this helmet study. B) Hands on trial is the method used. C) Discussion throughout the day was focused on the safety of each style helmet and differences in the helmets. D) Start to finish was active hands on and then ranking the helmets by preference in a gridsheet. E) Participants received healthy treats: apple, dark chocolate, cookie and non-edible goodies: pen, magnet, sunscreens, and vitamin E oil.
Evaluation Procedures: The outcome will be measured based on the helmet ranking of each participants. The results of which will be used in the research project.
Materials and Aids: 5 helmets with similar price range=$100 spread max. (different styles/types/brands); 2 assistants to observe and measure; area to set up obstacle=this trial used a metal gym weight holder as an object to crawl under and step over ; goodies; forms to document results; pens; goniometric tool to measure range of motion; disinfectant spray to prevent germ spread; clipboards.

*note: This safety trial was conducted during National Safety week for Fire and EMS. All participants will receive a certificate of participation and appreciation to be placed in their file and for their records.

Appendix D

List of Participants

James Bland

A shift

Leonard C. Taft
Jason R. Highfill
Jeffery T. Harbuck
Timothy P. Will
Antwan Lewis
Carlos Cruz
Michael J. Rafferty
Tonja L. Heer
Kethon J. Colbert
Steven A. Taft
Michael E. Rowley
Dwayne Thibeault
Nathanael Barnes

B shift

Brad L. Dyess
Evan C. Schantz
Adrian J. Killins
Jessica A. Forte
Jeffery J. Devlin
Michael T. Gocke
Joseph J. Lekan
Julian D. Pompi

C shift

Kristine Gray
Anthony McCulley
Chris Hughes
Michael G. Farrah
Danny L. Owens
Yusuf H. Abdullah
John C. Garcia
Anthony T. Russo
Corey M. Hazen
Greg F. Brocksmith
John R. Mcinarny
Quincey L. Heard
John R. Pasternak
Raymond C. Plumley
Michael A. Sherrier
Daniel Sanchez
Cody D. Case
Jonathan Patino